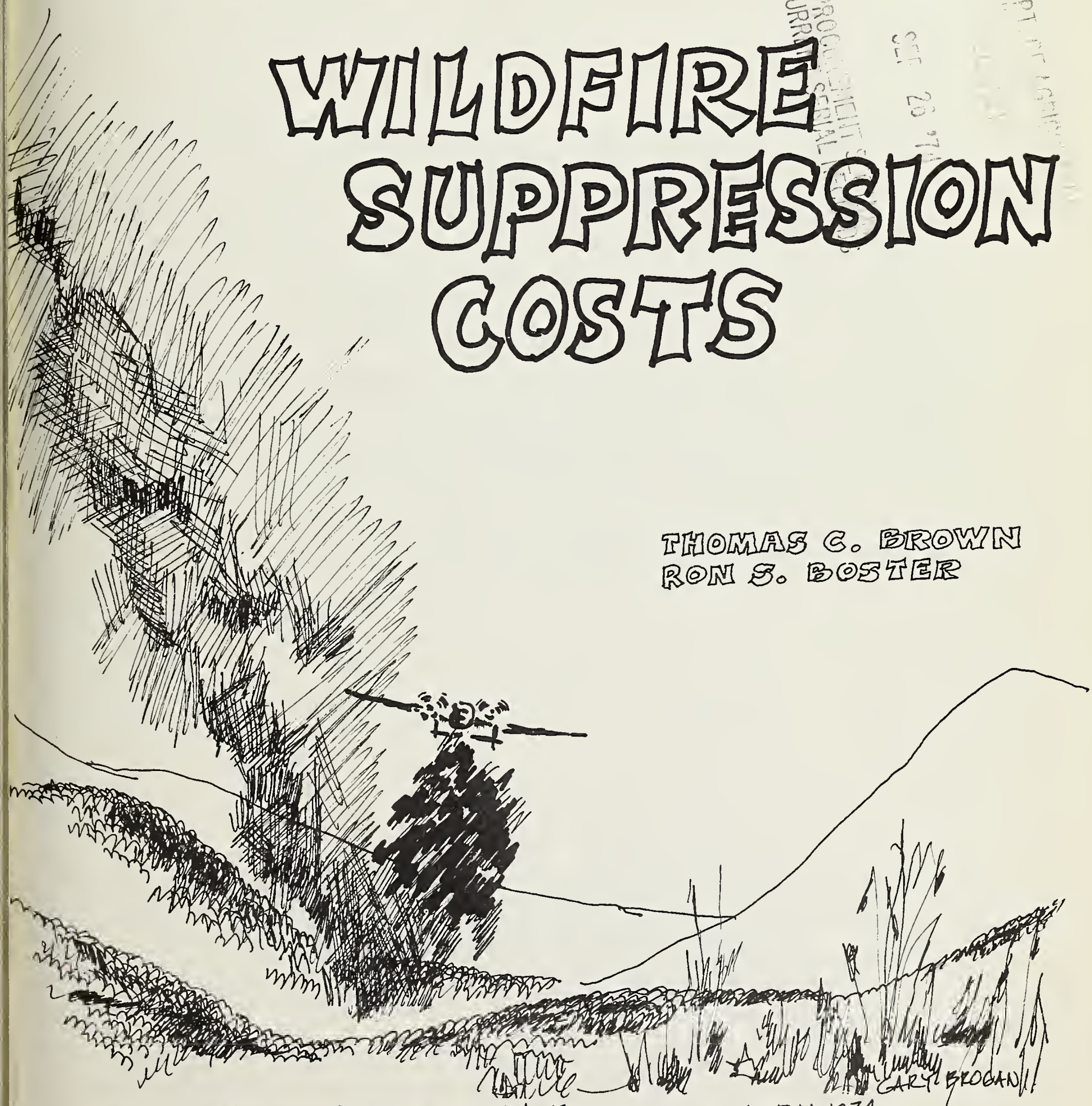
EFFECTS OF CHAPARRAL -TO- GRASS CONVERSION ON WILDFIRE SUPPRESSION COSTS



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Abstract

Properly planned, carried out, and maintained, chaparral-to-grass conversions should reduce the occurrence of large, expensive wildfires. Dollar values of "fire benefits" were calculated for 141 convertible areas in Arizona's Salt-Verde Basin. Case histories of large chaparral fires are analyzed to illustrate principles of chaparral and grass fires in the Southwest. Historical fire data were used in a predictive model, but where data were absent or insufficient, parameters were varied within specified limits. The fire benefit, though not as high as water and forage benefits resulting from conversion, is an important addition to a benefit-cost analysis. The fire benefit varies significantly from area to area because of differences in man-caused and lightning risks, and also in accessibility. While transference of dollar values to other areas is tenuous, the methodology is transferable and can be a very useful planning tool.

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Effects of Chaparral-to-Grass Conversion on Wildfire Suppression Costs*

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Contents

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If properly planned, carried out, and maintained, chaparral-to-grass[1] conversions can favorably influence water yield (Hibbert and Ingebo 1971), forage (Pond 1967), sediment (Boster and Davis 1972), recreation (O'Connell 1972a),[2] and wildlife habitat (Reynolds 1972). Practical experience has reinforced research findings. Conversions are costly, however, and the increased productivity is less than certain. The relevant question, therefore, is: are the conversion benefits worth the costs?

A truly comprehensive economic analysis of chaparral-to-grass conversion requires a full accounting of all the relevant costs and benefits. The total benefit is the sum of the individual benefits attributable to specific resources or products. The costs of chaparral-to-grass conversions are reasonably well known, as are the benefits from the traditional watershed products — water, forage, and recreation (O'Connell 1972b). There is, however, one benefit resulting from conversion that never has been adequately identified. This "fire benefit" is illustrated by the following example.

For 7 days in May 1972, the Battle Fire raged on the Prescott National Forest, Arizona — the first Class E or larger (300 acres and above) fire on that Forest in 14 years. The fire started in an area that was a classic conversion site — gentle slopes, good access, and dense brush — and burned 14,000 acres of chaparral plus 13,500 acres of pine and mixed pine and chaparral. The suppression cost was $1.4 million. The intense heat of this wildfire destroyed more organic matter and left the soil more vulnerable to erosion than would a properly planned prescribed burn. Ironically, the Battle Flat area (where the fire started) was planned as a conversion project 6 years earlier, but funds never were made available. There is general agreement that, had the area been converted to and maintained as weeping lovegrass *(Eragrostis curvula)*, a fire starting under identical conditions would have been held to approximately 160 acres at a probable suppression cost of less than $12,000.

Only through hindsight could one argue that the Battle Flat conversion would have been economical. Battle Flat was not the only candidate for conversion, nor was it the only target for a fire. This example should be taken only as illustrative of how conversion of chaparral to grass can decrease the occurrence of large, expensive fires. Once this obvious, but elusive, benefit is quantified, it can be incorporated into a comprehensive management framework that considers all products and alternatives in relation to costs.

Conversion of a chaparral area to grass is generally thought to contribute two fire-related benefits: (1) a decrease in wildfire suppression costs, and (2) a reduction in resource damage. This study is restricted to consideration of the first category only.

There can be no argument that wildfire often does great harm. Watersheds are not, however, vulnerable to total "destruction" as often implied by reported damages. Land does not stay damaged forever, so that damages in excess of either the market or productive value of the land defy economic logic. Besides, resource damages should be balanced with ecologic and productive benefits which also often result from wildfires. Fire-caused land damages and benefits are complex topics deserving special treatment, and therefore are deferred to a future study.

Specifically, then, this Paper concentrates on the benefits associated with conversion of chaparral to grass attributable to the reduction of fire suppression costs. Because of esthetic, wildlife, recreation, and soil considerations, only a 60 percent conversion is assumed. Thus, either isolated patches of chaparral are left untreated within the conversion area, or such patches are allowed to return to a chaparral cover following initial brush treatment.

Study Area and Methods

The Salt-Verde Basin — an 8.4-million-acre watershed in Arizona defined by the drainage of

[1] *The Arizona chaparral type consists of broad sclerophyll shrub communities of mostly low-growing, moderate to deep-rooted species with thick evergreen leaves. Shrub live oak* (Quercus turbinella) *is the dominant species of most stands.*

[2] *More information is available in a larger in-Service report available upon request from the Rocky Mt. For. and Range Exp. Stn., Tucson, Arizona.*

the Salt and Verde Rivers above Granite Reef Dam (fig. 1) — was the study area for this investigation. The Basin is the most important water-producer in the State; cattle grazing and timber production are significant land uses, and the Basin also offers outstanding outdoor recreation opportunities.

The Salt-Verde Basin contains approximately 1 million acres of chaparral. Some of this chaparral acreage is convertible, and conversion would increase wildland productivity in many instances. Not surprisingly, considerable interest exists across a broad spectrum for comprehensive study of the economics of such conversions.

Briefly, the study method was as follows. Possible conversion areas within the study area were identified (Brown 1973), and the fire histories of these and adjacent chaparral and grass areas were documented. These data, along with supplemental information regarding fire behavior, occurrence, and suppression costs, were then examined within an economic framework to determine the fire-related benefits of chaparral-to-grass conversions.

Chaparral Wildfire

Considerable money is spent each year on the Tonto and Prescott National Forests fighting chaparral wildfires. From 1962 to 1972, 420 chaparral fires were reported on the Tonto; 137 on the Prescott. Each of these fires required some action by Forest Service personnel; per-fire suppression costs ranged from near zero to more than $1 million.

The probability of a fire start can be described as a function of fire hazard and risk (Deeming et al. 1972). Fire hazard is determined by weather and fuel conditions. The important weather variables are present and antecedent temperature, humidity, and rainfall. High temperatures and low humidity favor fire starts.

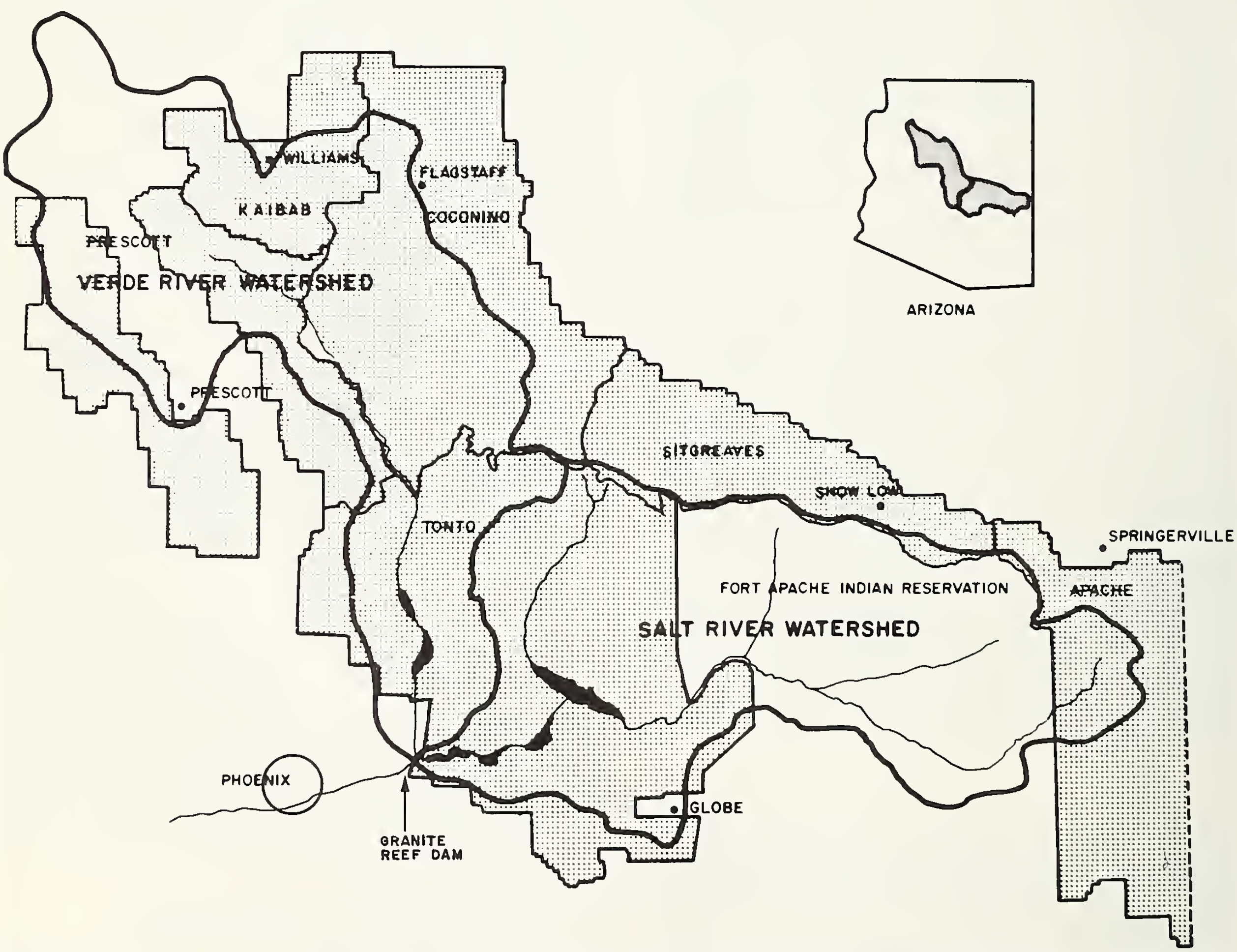

Figure 1. — Salt-Verde Basin, including the Prescott, Kaibab, Coconino, Tonto and Apache-Sitgreaves National Forests.

The longer these conditions persist in any particular season, the more likely fires become. Previous season's rainfall is important because rainfall favors growth of grasses and forbs, which are easily ignitable when cured.

The fuel situation in chaparral depends, in large part, on the amount of cured grass and dead, desiccated chaparral present in the stand. Sparse chaparral stands usually have grass and/or forbs between the bushes (unless the area has been overgrazed). In these areas, herbaceous growth is often as important as the chaparral in carrying a fire. In denser chaparral stands, which have less grass, fire starts are less frequent; fires, when they occur, are fierce and literally jump from one chaparral clump to another (Lindenmuth and Davis 1973). Several years are required for chaparral alone to produce sufficient fuel to carry a fire. Pond and Bohning (1971) estimate that at least 10 to 15 years are generally required for a shrub live oak stand to reburn. Baldwin[3] has estimated that, for Arizona, a dense chaparral stand normally will not burn for 15 to 20 years following a fire, and that about 35 years may be required for sufficient fuels to develop to support a conflagration.

Risk of wildfire (the probability of ignition) is a function of access, human use, and lightning incidence. The better the access to an area and the more human use it receives, the greater the chance of a man-caused fire start. Likewise, the more often lightning strikes an area, the greater the chance of a lightning fire start.

The size a fire will reach depends on a combination of natural and man-influenced variables. Weather is important, particularly wind, temperature, net radiation, humidity, and rainfall. Topography, too, is important, especially in conjunction with wind. Fuels must be dense and dry for a large fire to develop (Lindenmuth and Davis 1973). Also, man's firefighting efforts and capabilities must be considered. Finally, seasonal variations in the above-mentioned factors are important.

Both detection and access help determine how soon a fire is attacked and controlled. While there is considerable variation in the ability to observe and reach the different chaparral areas in the Salt-Verde Basin, this variation has lessened considerably in recent years with technological advances. Air surveillance can locate fires far from lookouts, and helicopters and air tankers can move men and equipment and drop fire retardant on target within minutes. The well-planned and relatively well-funded fire suppression efforts of the Forest Service hold most fires to within a few acres. However, even with the current sophistication, occasionally a fire — such as the Battle Fire — escapes.

Effect of Conversion on Wildfire Suppression

A 60 percent conversion of dense chaparral stands to lovegrass has a definite effect on firefighting efforts in and near the conversion areas. The probability of a fire start is influenced by the changes in vegetative cover (hazard) and access (man-caused risk). Likewise, the ultimate size of a fire starting in or near the conversion area will be influenced by the change in fuels and available access.

For illustrative purposes, we divided post-conversion fires into two categories: fires starting in a converted area (onsite effects) and fires starting near an area (offsite, or fuelbreak effects). Two case studies are presented in each category.

Onsite Effects of Conversion

The use of either weeping lovegrass or Lehmann lovegrass (*E. lehmanniana)* is assumed as the conversion species. Although easier to establish and more palatable to cattle, Lehmann lovegrass is subject to winterkill at higher elevations. Under normal moisture conditions in the chaparral country of central Arizona, these exotic (originally from Africa) perennial grasses are green from April to October.[4]

The likelihood of a fire start and the subsequent fire size depend, in part, upon the amount, proportion, and distribution of cured grass. Cattle grazing and prescribed burning help to control accumulations. However, because proper grazing management utilizes approximately 50 percent of a season's grass growth (Leithead 1963, USDA-Forest Service 1965), and because maintenance burns should be spaced 3 to 4 years apart, some cured grass will be held over most years. The probability of a fire start is very low immediately following either an initial (conversion) burn or a maintenance burn because of the lack of cured grass. The probability that a start will develop into a large fire is also significantly reduced during the same period.

The likelihood of a fire start increases as cured grass accumulates (especially in dry years immediately following a season of high herbage

[3]*Personal communication with Joy J. Baldwin Staff Officer, Tonto National Forest, USDA Forest Service, Phoenix, Arizona. 1972.*

[4]*More detailed botanical information about these grasses may be found in Crider (1945) and Humphrey (1960,1964).*

production). However, grass fires are generally easier to control than dense chaparral fires for several reasons: (1) grass fuels are finer than chaparral, making slurry much more effective and backfiring more feasible; (2) access is easier; (3) green lovegrass, present most years during the fire season, reduces the rate of spread, fire intensity, and flashiness; and (4) during a dry or low forage production year, grazing use will be above normal, which will reduce fuel concentration. Two examples of large chaparral fires which started in possible conversion areas illustrate these points.[5]

The **Boulder Fire** (fig. 2) burned 21,700 acres of brush and grass on the Tonto National Forest from June 13 to 25, 1959, and cost $567,408 to suppress. During the first 3 days the fire spread entirely within a chaparral area with

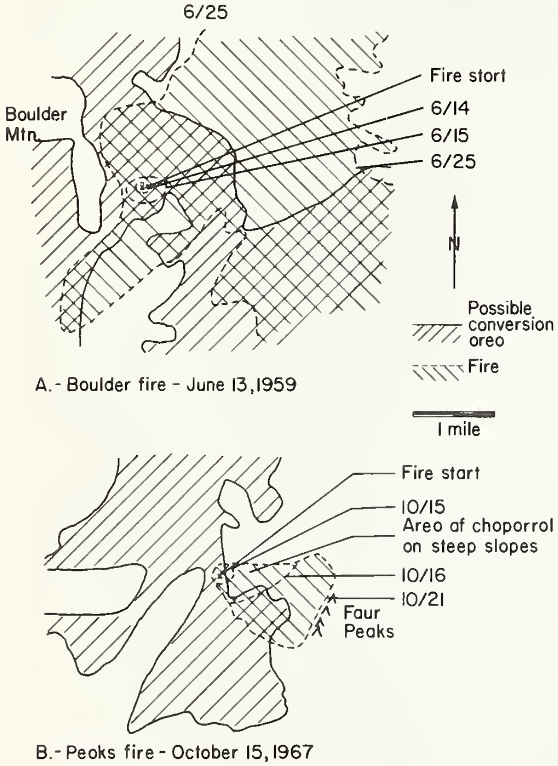

Figure 2. — Two fires used as examples for onsite effects of conversion: A, *Boulder Fire, June 13, 1959;* B, *Peaks Fire, October 15, 1967.*

possibilities for conversion to lovegrass. The fire did not spread far those first 3 days because about 0.5 inch of rain fell on the area the day the fire started. Reasons given for not controlling the fire were (1) very poor access due to lack of roads and dense brush, (2) too little fire retardant, and (3) the "extreme weather conditions" (high temperatures and strong, gusty, variable winds) which developed on June 16 (USDA-Forest Service 1959).

The spring and summer of 1958 saw a bumper grass crop in most parts of the State which would have resulted in a high carryover of grass herbage unless a maintenance burn followed in early 1959. Precipitation for the winter of 1958-59 was below average so that, by mid-June there may not have been much green lovegrass had the area been converted.

However, given the same attack methods and weather conditions, it is the consensus of experts that, with conversion, the fire would not have developed as it did. If the grass were sufficiently green, the rainfall and resultant humidity might have prevented or at least constrained the fire in its early stages; if not, the two slurry drops on June 14 probably would have been adequate to permit control. Even if they had failed, the men who reached the fire on the 14th could have used the grass for backfiring. Furthermore, foot access would have been improved because of the conversion.

The case of another large chaparral fire which started in a possible conversion area is quite different. The **Peaks Fire** (fig. 2) started October 15, 1967, and was controlled 6 days later at a cost of approximately $30,000. A total of 680 acres, mainly of dense brush, burned near Four Peaks. The fire burned within a possible conversion area during the first day, but moved into an area of chaparral too steep for conversion by the second day. The possible effect that conversion to lovegrass might have had on the fire depends in large part on how green the grass would have been that October 15.

In fact, 1967 was a dry year; January-September rainfall was 37 percent below normal, and no rain was recorded in October (average October precipitation is 1.59 inches). It is therefore reasonable to expect that any grass would have been cured by the middle of October. If grazing use had been light, the accumulated cured grass would have allowed the fire to spread faster than it actually did in the dense chaparral. If grazing had been normal, however, the light herbage production resulting from the low precipitation would probably have been largely consumed, so that fire spread would have been impeded. Regardless, the three men who arrived the first day might have been able to use the grass to backfire. In any case, no firm conclusion is possible.

[5] *The two fires described as case studies here and the two fires used as case studies in the following subsection were the only Class E or larger fires (300 acres and above) in or near possible conversion areas in the Salt-Verde Basin for which detailed fire reports were available. The Battle Fire occurred outside the Basin.*

The Fuelbreak Effect of Conversion

Conversion could have two beneficial effects on fires starting near converted areas. First of all, access to the area may be improved because of roads installed for the conversion or because of the removal of heavy brush in the area. More important, however, is the fuelbreak provided by the conversion area. If the fire moved in the direction of the converted area, it would stop at the conversion area if the grass were mostly green and/or closely grazed. If the grass were largely cured, a sufficiently rapid attack would permit it to be used for backfiring or slurry deposition. The presence of a converted area in the vicinity of a fire start could therefore permit firefighting efforts to be concentrated elsewhere.

The **Soldier Fire**[6] (fig. 3) which started about 150 yards from a possible chaparral conversion area, burned 4,700 acres west of Four Peaks from July 3 to July 7, 1970, and cost $375,000 to suppress. The fire moved mainly to the west and south, in the direction of the possible conversion area. Because of below-average January-to-June rainfall, a lovegrass stand would probably have contained a large proportion of cured grass unless it had recently burned. If recently burned it would have held the fire in its southerly and westerly spread; if cured, it could have been used for backfiring. Regardless, there should not have been much trouble in holding the fire in either direction. More effort could then have been centered on keeping the fire from spreading to the north and east.

A total of about 150,000 gallons of slurry, dropped by 11 planes, was used to fight the fire. The actual drop times are unavailable, but a conservative estimate is that if eight planes had each made three drops the morning of July 4 to suppress northerly and easterly spread (a total application of about 43,000 gallons of slurry), the fire would have been controlled by noon on July 4 and held to less than 500 acres.

The **Buckhorn Fire,** northwest of Roosevelt Lake, provides another example of the fuelbreak effect (fig. 3). The fire started June 14, 1966, and was controlled 6 days later, at a cost of $122,269, after having burned about 8,000 acres of brush and native grass. The fire started in mixed brush and grass on steep slopes between two possible conversion areas. Typical of fires which rely on desert grass for fuel, the fire quieted down early in the morning, June 15, and did not pick up again until midmorning. During this time 50 men arrived at the fire, which was then about 200 acres. Even with the aid of slurry, however, they were unable to control the fire.

Had the areas to the east, south, and north-northwest been converted to lovegrass, their firefighting efforts would likely have been more effective. The fire would have been held at the conversion areas if maintenance burns had preceded the wildfire that year. Otherwise, the lovegrass might have been green enough to hold the fire (this is not certain because of below-average rainfall in 1966); if not, the firefighting crews could have backfired from the grass. In either case, men and slurry could have concentrated on fighting the fire spread in directions not protected by conversion. During the time the fire quieted down, the 50 men more easily could have controlled the spread to the northeast by merely closing off the gap between the two possible conversion areas. Even if the fire had burned to its ultimate boundary to the southwest, the fire would still have been held to roughly 2,400 acres.

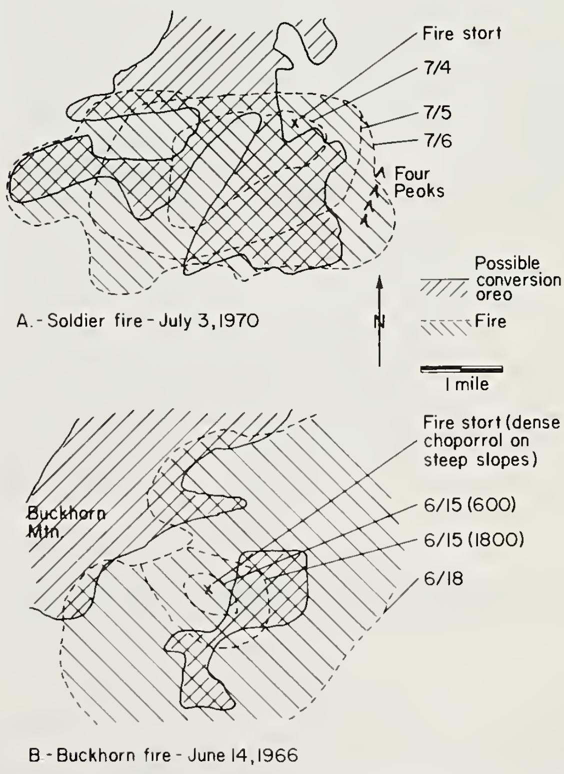

Figure 3. — Two fires used as examples for the fuelbreak effect of conversion: A, Soldier Fire, July 3, 1970; B, Buckhorn Fire, June 14, 1966.

[6]From figure 2, it appears the Soldier Fire burned the same area in 1970 that the Peaks Fire burned in 1967. Although the fire report for the Soldier Fire only delineated the outside fire boundaries, that Fire actually burned around the Peaks burn, and only entered the perimeter of the earlier, cooler burn where stringers of unburned brush remained.

Analysis Framework

Water and forage benefits arise from increased productivity, and are properly classified as "profit" maximization benefits. The fire benefit, so-called, is clearly a cost minimization benefit; the greater the reduction in firefighting costs, the greater the benefit. All benefits arising from conversion of chaparral to grass do, however, have one main commonality — they vary from year to year depending upon weather, management, and conversion maintenance. The problem is to estimate the yearly values.

Of the 1 million acres of chaparral within the Salt-Verde Basin, about 85 percent is on National Forest lands. Only part of this National Forest chaparral land, however, is suitable for conversion. Brown (1973) delineated 141 areas within the Basin, encompassing 354,000 acres of National Forest chaparral, for future conversion consideration based on three criteria: (1) chaparral crown cover greater than 30 percent, (2) slopes less than 60 percent, and (3) chaparral not in a wilderness or primitive area. The sizes of these areas range from 88 to 12,160 acres; the average size is 2,443 acres. The analysis that follows is based on the fire histories of these 141 areas.

We used the "with and without" procedure (U. S. Senate 1962). Estimated fire suppression costs with conversion were compared with estimated costs without conversion; the difference between them was the fire benefit. Present Forest Service wildfire suppression policy and practices were assumed. The basic items of information required were: (1) fire suppression costs by fire size class, (2) average annual number of fires per area, and (3) distribution of fires by size class.

Average annual fire suppression costs (C) for area i may be expressed as:

$$C_i = \sum_k N_{ik} c_k \qquad [1]$$

where,

N_{ik} = average number of class k fires in area i

c_k = average suppression costs of a class k fire.

Written another way,

$$C_i = N_i \sum_k p_{ik} c_k \qquad [2]$$

where,

N_i = average annual number of fires in area i

p_{ik} = proportion of class k fires in area i

Equation 2 contains the three basic parameters (above) as factors. Each parameter can be expected to differ for the two conditions — with conversion and without.

National Forest fire records provided the necessary data. Individual fire reports were useful data sources. Unfortunately, a generally observed Forest Service policy directs that these reports be destroyed after 10 years. Because much relevant fire data was thereby eliminated, an iteration approach was taken; where there was uncertainty over a parameter value, the parameter in question was varied over a range deemed inclusive of the true value. Table 1 summarizes these parameter variations — resulting in 252 alternatives — for the "with" and "without" conditions.

Table 1.--Summary of parameter variations, Salt-Verde Basin, Arizona

Parameter	Without conversion	With conversion
Fire occurrence	Computed from historical record	Factors 0.5-1.0 by 0.1 increments applied to the preconversion historical record (6 cases)
Fire size class distributions	Computed from historical record two ways: (1) Basinwide data: and (2) Ranger District data (2 cases)	Three postulated: (1) eliminate Class E and larger fires (2) eliminate one-half of Class E and larger fires (3) same as without conversion (3 cases)
Fire suppression costs	Classes A, B, and C computed from recent record for chaparral fires in Salt-Verde Basin; D and E+ fires cost from $15 to $75 per acre by $10 increments (7 cases)	Classes A, B, and C computed from recent record for grass fires in Salt-Verde Basin; D and E+ fires --same iterations as for preconversion (1 case)

The annual fire benefit (B) for each area (i) and for each alternative considered (j) is simply the difference between the with (C′) and without (C″) conversion wildfire suppression costs,

$$B_{ij} = C''_{ij} - C'_{ij} \qquad [3]$$

Fire Occurrence

Fire occurrence maps, which pinpoint fire locations, were used to develop average fire occurrence rates (N_i in equation 2) for each of the 141 areas. The number of fires per area divided by the years of record gives an estimate of the average number of fires per year in an area. These averages ranged from zero to 3.0, with an average of 0.31.

Some might argue that because the length of record (24 years for most areas) is close to the minimum length of the chaparral fire cycle, individual area fire occurrence rates are only crude approximations of the true rates. This would be true were it not for the fact that natural fire cycles have for many years been interrupted by the Forest Service's wildfire suppression efforts. The many chaparral fires which have occurred have covered a rather small acreage, the result of the vast majority of wildfires being held to below 10 acres. Consequently, most areas under consideration here tend to be at or nearly at the end of their fire cycles, so that a 24-year record is probably adequate to obtain representative fire occurrence rates. Two points follow from this reasoning: (1) because most areas are at or nearly at the end of their fire cycles, fire occurrence rates will tend to be higher than they would be without the suppression program, and (2) large differences in fire occurrence rates between areas, which were not uncommon, very likely stem from intrinsic differences between the areas rather than from differences in position within the fire cycle.

Neither research nor management experience permits accurate estimates of postconversion fire occurrence. With inadequate maintenance, postconversion fire start rates may actually increase. However, with proper grazing management and an adequate maintenance commitment, fire start rates should vary from very low immediately following a maintenance burn to near-preconversion levels at the end of each maintenance cycle (3 to 4 years). Between these extremes is a fuel condition representative of an area's average postconversion fire hazard and associated with this condition is a fire start rate useful for long-range analysis. To account for our inability to justify any single value, a range of values, based on a canvass of chaparral fire experts, was used (table 1).

Fire Size Class Distribution

The Forest Service classification scheme was used for this parameter, though Class E and larger fires were aggregated into one category — "E+" — because of the relative infrequency of large chaparral fires in the Basin (table 2). Two average fire size class distributions were computed for the Basin, one from all chaparral fires and one from fires only occurring in the 141 areas (table 2). The two distributions are obviously similar; we used the latter because it was derived directly from fires in the 141 areas.

Size class distributions for these areas by each Ranger District (table 2, lines 3-12)[7] were also used (see table 1). Basin Ranger Districts obviously experienced varying degrees of chaparral fire suppression success; differences in weather, topography, fuels, and distance from suppression-related facilities (for example, airports, lookouts, and crew locations) are probably the main reasons. Because three Districts — Cave Creek, Chino Valley, and Verde — had few fires (table 2), their distributions are subject to considerable error; thus, the more aggregative Basinwide distribution (table 2, line 2) provided a useful check.

We reported the Battle Fire and the four Basin fires (which, as noted above, were not selectively chosen) to help describe the effect of conversion on wildfire suppression efforts. In all but one case, fire experts agreed that prior conversion, with maintenance, would have allowed firefighters to hold the fires to smaller size. We believe that conversion on other areas would have similar effects.

Probably, the most optimistic change in the postconversion fire size class distributions would be the elimination of all E+ fires in the vicinity of conversion sites. Although conversion will probably be quite effective in eliminating the very costly, large E+ fires, all E+ fires will not likely be eliminated. A more conservative and realistic expectation would be the elimination of half of all E+ fires. The lowest estimate is no change at all in the size class distribution following conversion (see table 1).

Fire Suppression Costs

Firefighting costs have skyrocketed during the past 2 decades. Updating suppression costs

[7]*Another fire occurrence distribution, derived from all chaparral fires by Ranger District, is statistically similar to the distribution based on chaparral fires only in delineated feasible conversion areas by Ranger District. The computed one-tail associated probability was 0.34, using the Wilcoxon Matched-Pairs Signed-Ranks Test (Siegel 1956, p. 75-88), indicating acceptance of the null hypothesis of "no difference."*

to current values would be difficult because of the unknown contribution from noninflationary causes such as the increased use of aircraft. Suppression costs for smaller fires have been reported only since 1970, but their high frequency of occurrence provided adequate cost estimates for classes A, B, and C chaparral and grass fires (table 3).

The scarcity of Class D and larger fires suggested the iterative approach described in table 1. The low value ($15 per acre) was reported by Suhr (1967, p. 24) as average for a project-size (Class E and above) chaparral fire in the Brushy Basin area of the Salt-Verde Basin. The high value ($75 per acre) is slightly above the per-acre cost of the 1972 Battle Fire, a high-cost fire.[8] These per-acre costs were then multiplied by the average size of D and E+ fires — 200 and 7,500 acres, respectively[9] — to obtain the average-suppression costs for Class D and E+ fires.

Table 3.--Average suppression costs for Classes A, B, and C chaparral and grass fires, Salt-Verde Basin, Arizona (data for 1970, 1971, 1972)

Class	Chaparral		Grass	
	Number	Average cost	Number	Average cost
A	132	$ 239	62	$ 204
B	37	1,632	42	485
C	15	2,994	19	1,646

Table 2.--Fire size class distributions (percent), Salt-Verde Basin, Arizona

Basis	Fire size class distributions						Number of fires
	A (0-1/4 acres)	B (1/4-10 acres)	C (10-100 acres)	D (100-300 acres)	E+ (300+ acres)	Total	
Basinwide data:							
1. All Basinwide chaparral fires	70	21	6	2	1	100	643
2. Fires in 141 chaparral areas	74	20	4	1	1	100	536
Ranger District data for 141 chaparral areas:							
Tonto National Forest--							
3. Cave Creek	37.5	37.5	12.5	--	12.5	100	8
4. Globe	47	39	11	3	--	100	74
5. Mesa	43	41	8	4	4	100	49
6. Payson	91	9	--	--	--	100	116
7. Pleasant Valley	84	15	1	--	--	100	102
8. Roosevelt	57	30	9	--	4	100	95
Prescott National Forest--							
9. Chino Valley	63	25	12	--	--	100	8
10. Thumb Butte	81	17	--	--	2	100	42
11. Verde	62	30.5	--	--	7.5	100	13
12. Walnut Creek	96	3	1	--	--	100	71

[8] *Personal communication with Frank O. Carroll, Division of Fire and Air Management, Southwestern Region, USDA Forest Service, Albuquerque, New Mexico. 1972.*

[9] *The average size of a Class D fire may be assumed to be 200 acres (a Class D fire is defined as from 100 to 300 acres). The average for the 17 recorded Basin Class E+ fires from 1955-72 was 7,401 acres ($S_{\bar{x}} = 2,146$).*

Results

For all alternatives (see table 1) and for each of the 141 chaparral areas, the expected fire suppression costs both with and without conversion were calculated and the differences (B_{ij}) taken. The per-acre fire benefit associated with each alternative is the weighted average (by area size) of the 141 B_i's for that alternative.[10] We believe these simulated fire benefits, which range from $0.03 to $1.13 per acre per year, include all reasonable possibilities of the average cost savings from conversion of dense chaparral in the Salt-Verde Basin.

What happens to the fire benefit if parameter values are fixed? In the following analysis, the two fire size distributions (Basinwide and Ranger District) are retained, but we substitute the following values for the previously varied parameters: a $45 per-acre suppression cost for D and E+ chaparral and grass fires (approximately the average uncompounded suppression cost of the nine E+ fires recorded in the Basin for which cost records exist), and a 20 percent reduction in fire starts following conversion (a reasonable assumption provided conversions are maintained every 3 or 4 years).

These assumptions were coupled with the three postulated postconversion wildfire distributions to yield three sets of fire benefits (table 4). What we would call the maximum arguable benefit is associated with a postconversion distribution with no E+ fires in or near conversion areas. The annual per-acre benefit for this alternative is $0.48 or $0.67 (table 4, line 1),[11] depending on which fire size class distribution is used.

A more conservative estimate — and one more appropriate for benefit-cost analysis — derives from the assumption that half of the proximate E+ fires are eliminated as a result of conversion. The annual per-acre fire benefits for this alternative are $0.31 and $0.43 (table 4, line 2).

A still more conservative assumption is that conversion will cause no change in the postconversion fire occurrence distribution. For this alternative, the benefit estimates are lowest — $0.13 and $0.18 per acre per year (table 4, line 3) — reflecting only the 20 percent reduction in fire starts and reduced costs of suppressing small (Class A, B, and C) grass fires rather than small chaparral fires.

How do these values compare with other wildland values (for example, water and forage benefits) which also may result from conversion of chaparral to grass? As with fire benefits, water and grazing increases (if any) will vary considerably across areas. Based on an exhaustive analysis of feasible conversion areas in the Salt-Verde Basin, Brown, O'Connell, and Hibbert[12] place the average annual forage benefit at over $1 per acre and the water benefit at about double the forage benefit. It is readily seen (table 4) that even for the maximum arguable fire benefit ("eliminate E and larger fires"), the annual forage benefit is twice and the water benefit more than four times as great.

From a management perspective, present values are generally more useful than annual values. As distinguished from annual value (reported above), present value is the current worth of the stream of yearly benefits over time. Derivation of present values requires discounting annual values over a specified planning horizon.[13] The midpoints of the three sets of annual fire benefits (table 4) were chosen as the annual values for discounting purposes: for "no change" the midpoint between 13 and 18 cents is 15.5 cents; for "eliminate one-half of E+ fires" the value is 37.0 cents; and for "eliminate E+ fires" the value is 57.5 cents. These per-acre values were discounted at two rates over a 50-year planning horizon — 6-7/8 percent as recommended by the Water Resources Council (1973, p. 86) and also at 10 percent, which some have argued is more appropriate (Cicchetti et al. 1973). At 6-7/8 percent the present values for these three alternatives, in order, are $2.17, $5.19, and $8.06 per acre; at the 10 percent rate the values are $1.54, $3.67, and $5.70 per acre (table 4).

[10]*The weighted average annual per-acre fire benefits for each alternative j may be computed from:*

$$\frac{\sum_i B_{ij}}{\sum_i A_i}$$

where,

B_{ij} = *fire benefit for area i and alternative j*

A_i = *size of area i in acres*

[11]*The additional elimination of Class D fires increases the benefit little because of the low incidence of D fires: the annual per-acre benefit range is from $0.49 to $0.68.*

[12]*Brown, Thomas C., Paul F. O'Connell, and Alden R. Hibbert. Chaparral conversion potential in Arizona. Part II: an economic analysis. (in preparation for publication, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado).*

[13]*If A_t represents the annual value in year t, then for a planning horizon of n years, the present value is expressed as:*

$$\sum_{t=1}^{n} [A_t/(1+i)^t]$$

where i is the interest or discount rate.

The cost savings (fire benefits) reported herein are averages and, as such, should not be applied to any particular area. The model did, however, provide fire benefit estimates for individual areas (not listed in this report). For all alternatives considered (see table 1), individual area savings (B_i) were less than the mean for approximately three-fourths of the 141 areas. Differences in fire occurrence rates were the major source of variation. With special scrutiny (for example, onsite inspection), these individual area estimates can be validated or modified to provide useful planning information.

Summary and Conclusions

Our primary objective was to evaluate how chaparral-to-grass conversion would affect wildfire suppression costs on 141 chaparral areas in the 8.4-million-acre Salt-Verde Basin of central Arizona. The quantification of this potential cost savings is a necessary input into any comprehensive economic analysis of chaparral conversion for the Basin. An important assumption was that current Forest Service wildfire policies remain essentially unchanged. Another assumption was that, as a result of proper site selection and properly managed conversions, adequate grass stands are established and maintained.

Conversion of chaparral to perennial lovegrass tends to cut firefighting costs. Initial conversion and subsequent maintenance will keep dry fuels at lower levels, thereby reducing the average number of fires per year. If fires do start in the converted areas, they are more easily controlled because of fuel reduction and improved access. Whether a fire starts in or near a converted area, the lovegrass can be used as a fuelbreak if green, or for backfiring if cured.

Over a wide array of simulated alternatives, the average annual per-acre cost savings (fire benefit) ranged from $0.03 to $1.13 across the 141 areas. Focusing on the more plausible parameter values and three postconversion fire size class distributions narrows this range considerably. If all Class E and larger fires are eliminated as a result of conversion — an optimistic, but not incredible, assumption — fire benefits are highest, the estimates being $0.48 and $0.67 per acre per year. These are the maximum arguable economic values. If only half the E+ fires are eliminated — a more reasonable expectation — the values are $0.31 and $0.43. And, if the postconversion fire size class distributions remains unchanged, the fire benefits are lowest, $0.13 and $0.18.

The wide variation in fire benefits among individual areas, coupled with the fact that three-fourths of the areas had per-acre benefits below the mean benefit, requires this caveat: these average fire benefits should not be applied to individual areas without special scrutiny. However, individual area fire benefits (from which the averages were calculated) may, with supplemental knowledge, provide useful planning information.

This study concentrated on a specific area — Arizona's Salt-Verde Basin — and the calculated fire benefits may not be transferable to other areas. The methodology, however, is transferable. The crux of the method is the widely accepted "with and without" procedure. The degree of iteration-simulation will depend upon data availability. But no matter how much

Table 4.--Estimated average annual per-acre dollar savings and present values from conversion of chaparral to lovegrass, Salt-Verde Basin, Arizona[1]

Postconversion change in fire class distribution	Range of mean annual per-acre savings[2]	Present values at:[3] 6-7/8%	10%
1. Eliminate E and larger fires	$0.48 - 0.67	$8.06	5.70
2. Eliminate one-half of E and larger fires	.31 - .43	5.19	3.67
3. No change	.13 - .18	2.17	1.54

[1]Assumes a $45 per-acre suppression cost for Class D and larger chaparral and grass fires, and a 20 percent reduction in fire starts following conversion.

[2]The left values were derived using Basinwide data; the right values were derived using individual Ranger District data.

[3]A 50-year planning horizon was postulated. The present values were computed from the midpoint value of the mean annual per-acre savings for each row.

or how good the data, there is no substitute for concomitant input from those with firsthand knowledge of the areas.

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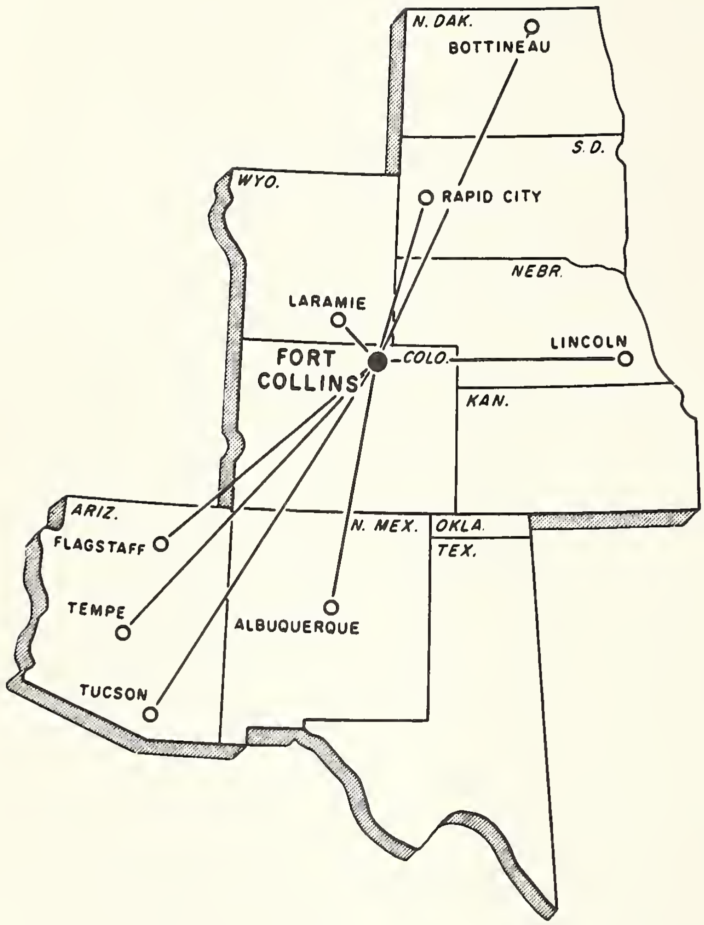
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